Name Notes Filled In Hour

Unit 8 Packet: Polarity and Intermolecular Forces

Learning Goals:

1. I can explain different characteristics of ionic and covalent substances.
2. I can calculate the difference in electronegativity between two atoms.
3. I can determine if the electronegativity difference makes a bond polar, nonpolar, or ionic.
4. I can explain what is happening to electrons within a polar bond.
5. I can list the intermolecular forces from weakest to strongest.
6. I can identify when hydrogen bonding will be present and explain its influence on a substance.
7. I can explain how intermolecular forces would influence the melting point of the substance.
8. I can explain why, at room temperature, some compounds are solids and others are gases.
9. I can explain why a compound that has stronger forces of attraction would have a higher melting point.

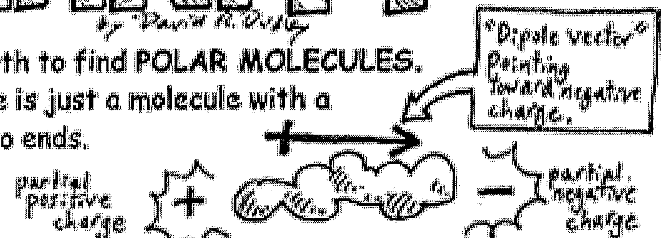
VOCABULARY (I can define/describe the following terms in my own words)

- boiling point
- dipole
- dipole-dipole attraction
- dispersion
- electronegativity
- hydrogen bond
- intermolecular forces
- melting point
- polarity

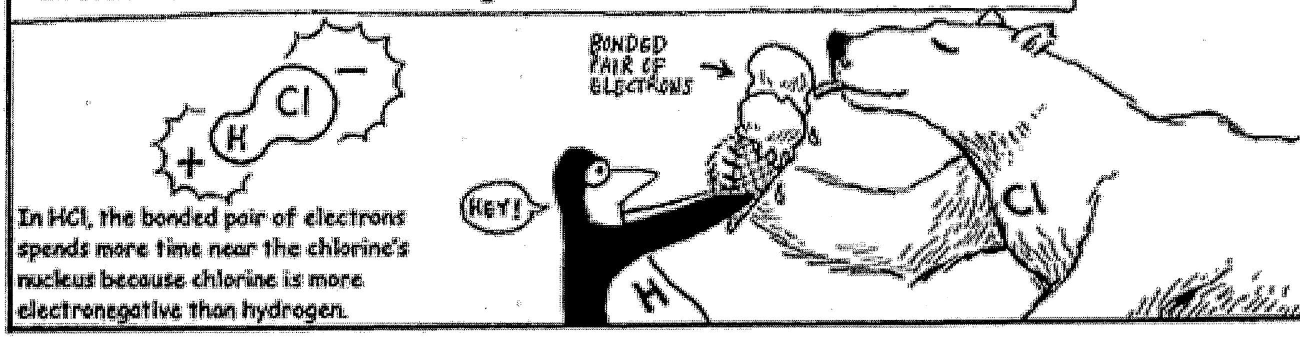
POGIL #1:

The BARE ESSENTIALS of POLARITY

You don't have to go to the ends of the earth to find POLAR MOLECULES. They're all over the place. A polar molecule is just a molecule with a difference in electrical charge between two ends.

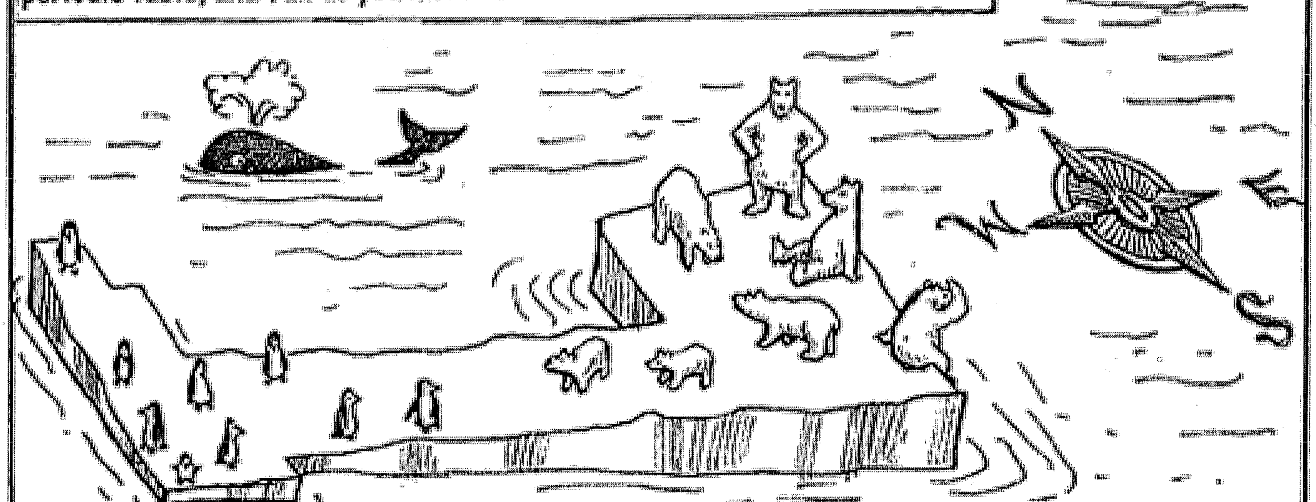


The electrical imbalance of POLARITY is caused by differences in ELECTRONEGATIVITY between atoms. Electronegativity is the ability of an atom/nucleus to attract bonding electrons toward itself.



In HCl, the bonded pair of electrons spends more time near the chlorine's nucleus because chlorine is more electronegative than hydrogen.

The periodic table shows a general trend in the electronegativity of the elements. Electronegativity tends to rise as you move "northeast" on the periodic table, and fall as you move "southwest."



Note: The noble gasses, in the periodic table's far right column, are often assigned an electronegativity value of zero because they are relatively nonreactive.

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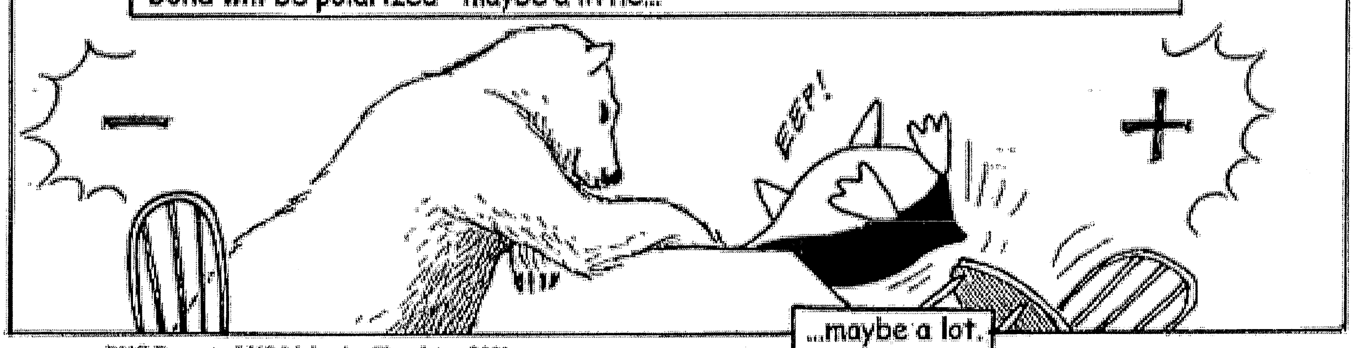
When two atoms with unequal electronegativity values bond, they do not share the bonding electrons evenly. The bonding electrons spend more time around the more electronegative atom, creating a PARTIAL NEGATIVE CHARGE on that atom. The other atom then has a PARTIAL POSITIVE CHARGE, and the bond is polar.

So the polarity of a bond is a function of the difference between the electronegativity values of two bonding atoms. Bonded atoms with equal electron-attracting strength will have nonpolar bonds.

However, if the electronegativity of two bonded atoms is unequal, then their bond will be polarized—maybe a little...



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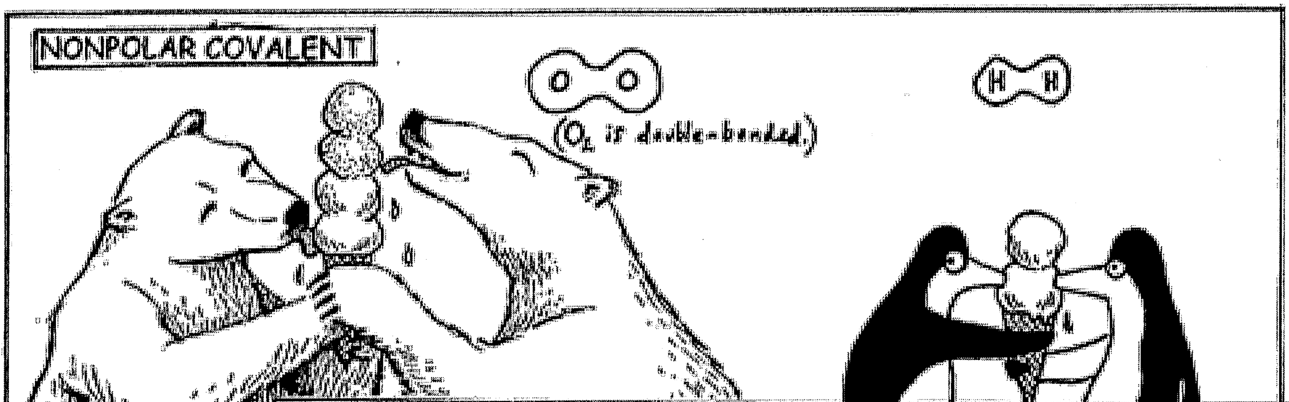
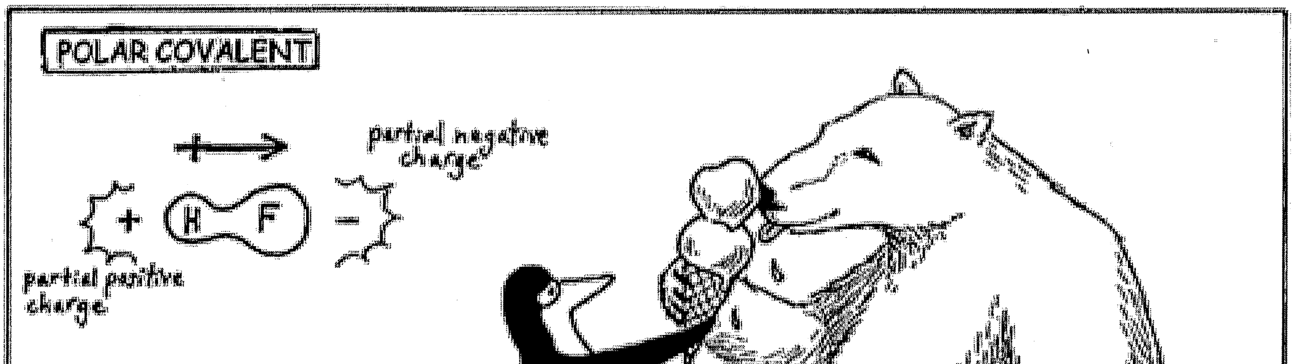
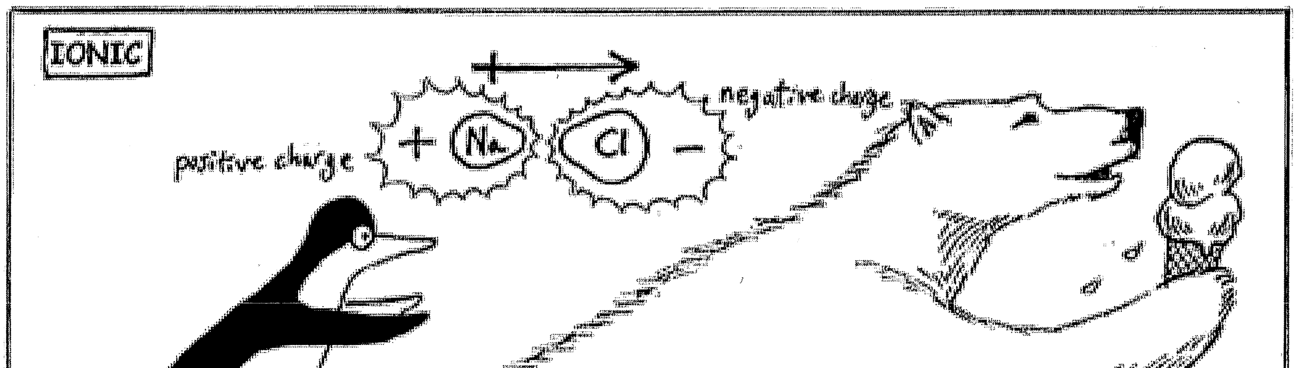
Because the elements have such varying electronegativities and can come together in so many different combinations, there is really a **CONTINUUM OF POLARITY IN BONDING**. For convenience, we can break the continuum down into three categories: (1) nonpolar covalent, (2) polar covalent, and (3) ionic.



The clearest examples of nonpolar covalent bonds are those between identical atoms, such as H_2, N_2, O_2, or Cl_2. Bonds between atoms with nearly the same electronegativity value, such as carbon and hydrogen atoms, are usually also considered nonpolar. Remember, this is really a continuum, and conventional distinctions are somewhat artificial.



In a polar covalent bond, two atoms still share bonded pairs of electrons, but those electrons are decidedly more attracted to one atom than the other. Examples include bonds between carbon and oxygen atoms, or between hydrogen and fluorine atoms.



At the extreme of difference in electronegativity, polar covalence shades into the winner-take-all situation of ionic bonding. The more electronegative atom seizes all the bonding electrons and becomes a negative ion, while the other atom becomes a positive ion. The opposite charges on the ions attract each other.

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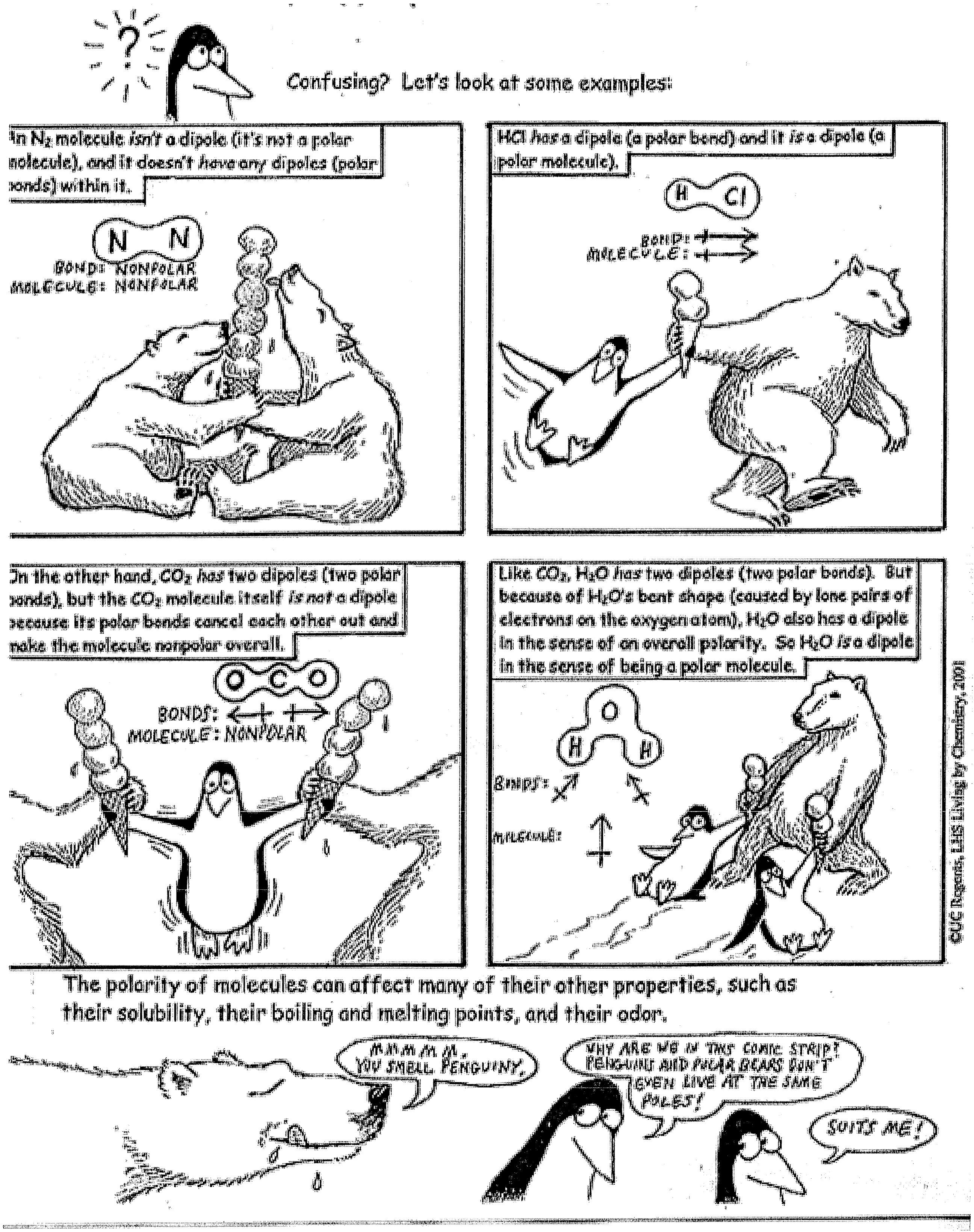
Polar bonds between atoms constitute **DIPOLES.** Actually, the word "dipole can refer to several different things that are relevant here: (1) the polarity of an individual polar bond between atoms, (2) the net polarity of a polar molecule that may have several polar covalent bonds within it, and (3) the polar molecule itself.



Summary of Info from POGIL #1

Tell me what you learned from this activity. Summarize in a list or a few short sentences.

Electronegativity and Bonding NOTES

Electronegativity: the ability of an atom to hold bonded electrons to it.

Ionic Bonding

- Formed when a metal bonds with a non metal.
- Electrons are gained or lost
- cation lose electrons
- anion gain electrons
  - One atom will lose electrons and the other will gain electrons forming oppositely charged ions, that become attracted to one another.
- Metals lose electrons because they have such a low ability to attract electrons and non-metals hava a high ability to attract electrons.
- Electronegativity Difference greater than 1.7
- Strongest kind of bond because they are made between oppositely charged atoms.

Covalent Bonding

- Electronegativity Difference less than 1.7
- When atoms have similar electronegativities, it means that each nucleus is attractive to electons and neither element is willing to give away its electrons.
- Electrons are shared
- Sharing may not be equal

Non-Polar Covalent Bonds

- Electronegativity Difference less than 0.5
- Nuclei are essentially equal in their level of attractiveness to electrons.
- Shared electrons will spend equal time around BOTH nuclei
- Electrons are shared equally

Polar Covalent Bonds

- Electronegativity Difference between 0.5 and 1.7.
- Electrons are NOT shared equally.
- Electrons are shared because one nuclei is not strong enough to take the electron from the other.
- The atom with the greater electronegativity is strong enough to "hog" the electron and not allow it to spend an equal amount of time around the other nucleus.
- Atom that "hogs" the electron acquires a slight negative charnge – not a full negative charge like an ion would but a partial charge.
- Atom with the lower electronegativity will acquire a slight positive charge because it is without the electron for some of the time.

Within a molecule a bond can be polar AND overall a molecule can be polar if it has an unsymmetrical polar bond. We will discuss polarity of molecules after we have learned the types of molecular shapes.

Rubberband Demo

DIRECTIONS: Draw a picture of each model. Explain what is happening to the electrons and if the bond is polar or nonpolar.

Styrofoam balls: 2 shared e^- **Rubber bands:** electronegativity

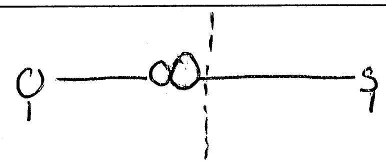
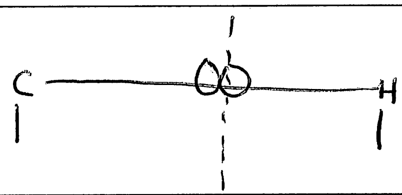
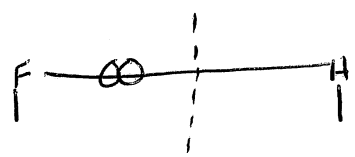
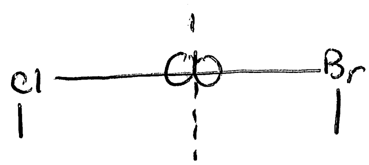
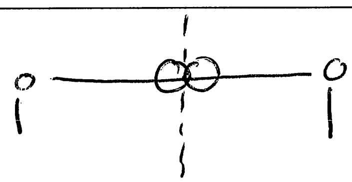
Elements in Bond	Drawing of Model	What is happening to electrons?	Type of Bond
O-S 3.5-2.5 1		electrons Shared but NOT Equal	Polar
C-H 2.5-2.1 0.4		electrons shared more equally than #1	Non-polar
F-H 4.0-2.1 1.9		electrons way closer to F than H. Not shared	Ionic
Cl-Br 3.0-2.8 0.2		electrons shared almost equally	Non-Polar
O-O 3.5-3.5 0		100% equally shared	Non-Polar

Table of Electronegativity Values

Electronegativity

0.5 - 0.9	2.5 - 2.9
1.0 - 1.4	3.0 - 3.5
1.5 - 1.9	3.6 - 3.9
2.0 - 2.4	4.0 +

1	2	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	3 (13)	4 (14)	5 (15)	6 (16)	7 (17)	8 (18)
H 2.1																	He --
Li 1.0	Be 1.6											B 2.0	C 2.5	N 3.0	O 3.5	F 4.0	Ne --
Na 0.9	Mg 1.3											Al 1.6	Si 1.9	P 2.2	S 2.5	Cl 3.0	Ar --
K 0.8	Ca 1.3	Sc 1.4	Ti 1.5	V 1.6	Cr 1.7	Mn 1.6	Fe 1.8	Co 1.9	Ni 1.9	Cu 1.9	Zn 1.7	Ga 1.6	Ge 2.0	As 2.2	Se 2.6	Br 2.8	Kr --
Rb 0.8	Sr 1.0	Y 1.2	Zr 1.3	Nb 1.6	Mo 2.2	Tc 2.1	Ru 2.2	Rh 2.3	Pd 2.2	Ag 1.9	Cd 1.7	In 1.8	Sn 2.0	Sb 2.1	Te 2.1	I 2.7	Xe 2.6
Cs 0.8	Ba 0.9	La 1.1	Hf 1.3	Ta 1.5	W 1.7	Re 1.9	Os 2.2	Ir 2.2	Pt 2.2	Au 2.4	Hg 1.9	Tl 2.0	Pb 2.3	Bi 2.0	Po 2.0	At 2.2	Rn --
Fr 0.7	Ra 0.9	Ac 1.1	Rf --	Db --	Sg --	Bh --	Hs --	Mt --	Uun --	Uuu --	Uub --		Uuq				

Ce	Pr	Nd	Pm	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu
Th	Pa	U	Np	Pu	Am	Cm	Bk	Cf	Es	Fm	Md	No	Lr

To Determine Polarity of a Molecule Notes

Step 1: Draw a Lewis's structure for the substance.

Step 2: Using electronegativities, identify each bond as either polar or non-polar.
(If the difference in electronegativity for the atoms in a bond is EQUAL to or GREATER than 0.5, we consider the bond to be polar. If the difference in electronegativity is LESS than 0.5, the bond is essentially nonpolar.)

- **If there are NO polar bonds, the molecule is Non-Polar.** (*UNLESS it is bent or pyramidal, then the lone pair influences the polarity*)
- If the molecule has polar bonds, move on to Step 3.

Step 3: If there is only one central atom, examine the electron groups around it.

- **If there are NO lone pairs on the central atom, and if all the bonds to the central atom are the Same, the molecule is nonpolar.)**
- If the central atom has at least one polar bond and if the groups bonded to the central atom are not all identical, the molecule is *probably* polar. Move on to Step 4.

Step 4: Draw a geometric sketch of the molecule.

Step 5: Determine the symmetry of the molecule using the following steps.

- Describe the polar bonds with arrows pointing toward the more electronegative element. Use the length of the arrow to show the strength of the polarities of each different bonds. (A greater difference in electronegativity suggests a more polar bond, which is described with a longer arrow.)
- Decide whether the arrangement of arrows is symmetrical or asymmetrical
  - If the arrangement is **symmetrical** and the arrows are of equal **length,** the molecule is non-polar.
  - If the arrows are of different **lengths**, and if they **do not** balance each other, the molecule is polar.
  - If the arrangement is asymmetrical, the molecule is polar.

Polarity of Molecules & Shapes

Nonpolar Molecule
Even distribution of electrons around the molecule

↓

Tetrahedral // **Linear** // **Trigonal Planar**
Only if molecule is *symmetrical*
OR
Contains all NONPOLAR bonds

Polar Molecule
Uneven distribution of electrons around the molecule

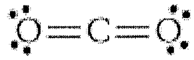
↓

Bent // **Pyramidal** — because of lone pairs!
Always polar!!!
Even if bonds within are not

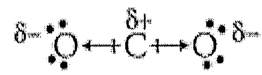
↓

Tetrahedral // **Linear** // **Trigonal Planar**
Only if molecule is *asymmetrical*
OR
Contains all one or more POLAR bonds

EXAMPLES – Predicting Molecular Polarity:

a. The Lewis structure for CO_2 is 

The electronegativities of carbon and oxygen are 2.6 and 3.4. The 0.8 difference in electronegativity indicates that the C-O *bonds are polar*, BUT the Symmetrical *arrangement* of these bonds makes the molecule **nonpolar**. If we put arrows into the geometric sketch for CO_2, we see that they exactly balance each other, in both direction and magnitude. This shows the symmetry of the bonds.



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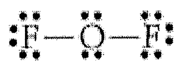
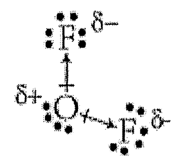
b. The Lewis structure for OF_2 is 



The electronegativities of oxygen and fluorine, 3.5 and 4.0, respectively, produce a 0.5 difference that leads us to predict that the O-F *bonds are* Polar. The molecular geometry of OF_2 is bent. Such *an* asymmetrical *distribution* of polar bonds would produce a polar **molecule**.

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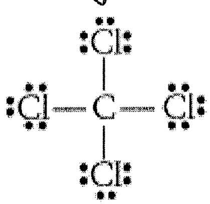
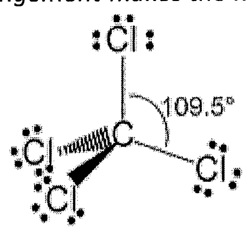
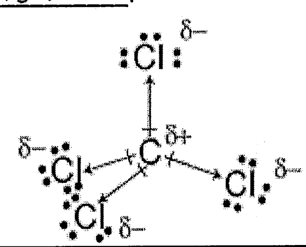
c. The molecular geometry of CCl_4 is tetrahedral. Even though the C-Cl *bonds are* polar, their symmetrical *arrangement* makes the molecule non-polar.







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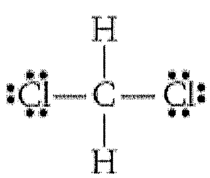
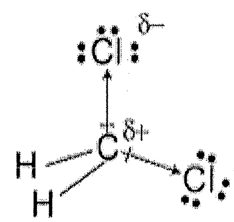
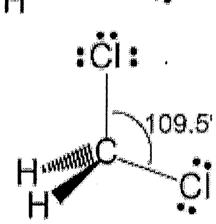
d. The Lewis structure for CH_2Cl_2 is…



The electronegativities of hydrogen, carbon, and chlorine are 2.1, 2.5, and 3.0. The 0.4 difference in electronegativity for the H-C bonds tells us that they are *essentially* non polar. The 0.5 difference in electronegativity for the C-Cl bonds shows that they are polar.





The following geometric sketches show that the polar bonds are asymmetrical arranged, so the molecule is Polar. (Notice that the Lewis structure above *incorrectly* suggests that the bonds are symmetrically arranged. *Keep in mind that Lewis structures often give a* false ***impression of the geometry*** *of the molecules they represent.*)

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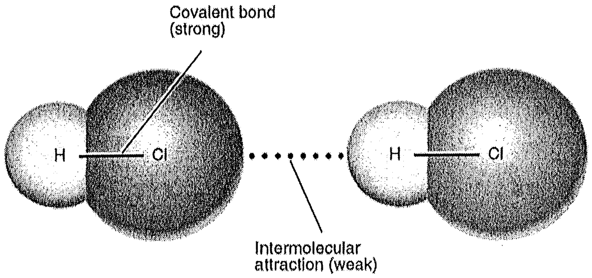
e. The Lewis structure and geometric sketch for HCN are the same: H—C≡N:

The electronegativities of hydrogen, carbon, and nitrogen are 2.1, 2.5, and 3.0. The 0.4 difference in electronegativity for the H-C bond shows that it is nonpolar. The 0.5 difference in electronegativity for the C-N bond tells us that it is polar. **Molecules with** One **polar bond are always polar.**

Intermolecular Force NOTES

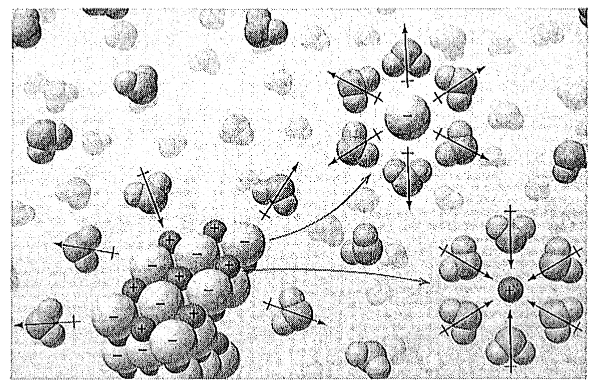
All matter is held together by force. The force between atoms within a molecule is a chemical or **intramolecular** force. The force *between* molecules is a physical or ***intermolecular*** force.



Charge-Charge Forces: These are the most attractive intermolecular forces. This is the attraction of one ion for another in an ionic substance. It is the strong attractive force that causes ionic solids to have extremely high melting points compared to covalent solids of similar mass.

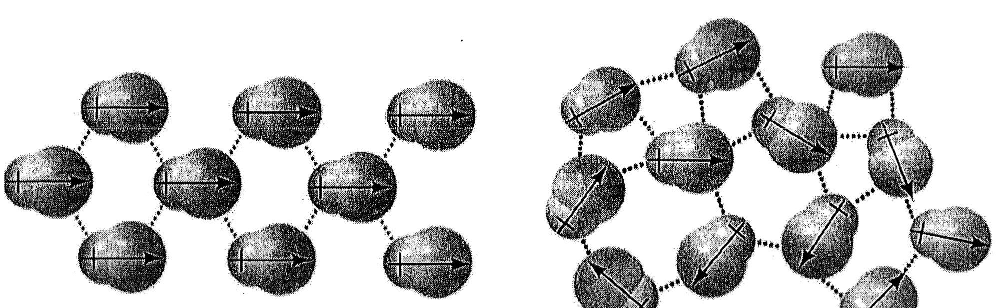
Charge-Dipole Forces: An uncharged (or covalent) molecule can still have an dipole moment. **Dipoles** arise from opposite but equal charges separated by a distance. Molecules that possess a dipole moment are called polar molecules.

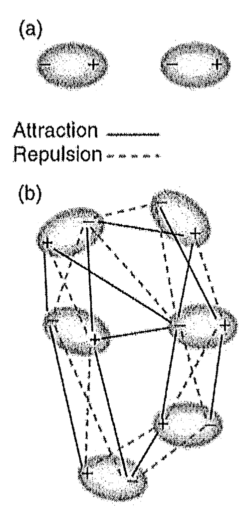
Water is polar because it contains 2 asymmetrical dipolar bonds. When salt is dissolved in water, the ions of the salt dissociate from each other and associate with the dipole of the water molecules.



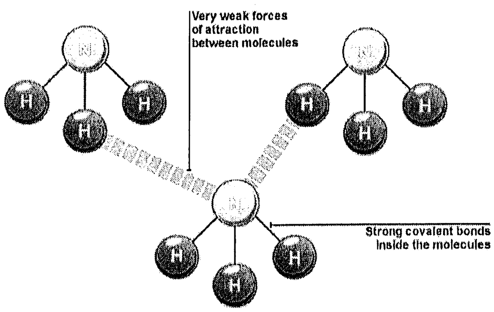
The collection of positive and negative charged particles on the left represents an ionic solid, such as NaCl. NaCl dissolves in water, the dipole of the water is attracted to the oppositely charged ion, causing the orientation of particles as depicted to the right.

Dipole-Dipole forces exist between neutral polar molecules. The partially positive charge at one end of the dipole molecule is attracted to the negative end of another dipolar molecule. On average, dipoles in a liquid orient themselves to form attractive interactions with their neighbors. This attractiveness is weaker than an ionic attraction or a dipolar attraction to an ionic substance.

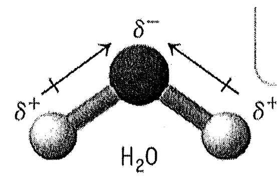




Notice the difference in entropy represented by these two pictures

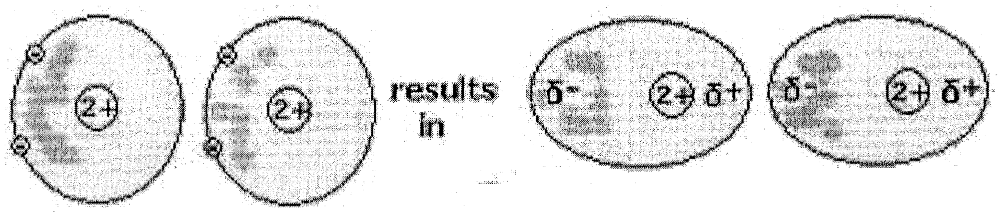


Hydrogen bonding is a type of dipole force, but one that specifically involves a polar bond to hydrogen. Since hydrogen makes the most polar bonds when sharing electrons with nitrogen, oxygen, **and** fluorine, these are the elements necessary for hydrogen bonding. Since these bonds have a high degree of polarity, they will have a *greater* strength of attraction than **any other** dipole to dipole attraction.



Dispersion is when two non-polar substances come near to one another and for a moment acquire a temporary dipole. This means that although they are nonpolar substances, for a short time, behave as if they are dipole. Dispersion will also occur when a nonpolar substance is near a polar or ionic substance.

Disperion occurs because the protons of one atom are attractive to the electrons of another when the molecules are in close proximity. When the electrons become attracted to another nucleus they are drawn toward it, giving that end of the molecule a slight negative charge. This leaves the opposite side of the molecule electron deficient and therefore, slightly positive.



As soon as the distance between the two molecules is increased, the temporary dipole disappears and the molecules return to their nonpolar state...until a close encounter with another molecule occurs, causing the dispersion forces to reappear.

To Sum Up:

The intermolecular forces (IMFs) important for you to remember are:

1. Hydrogen Bonding
2. Dipole - Dipole attraction
3. Dispersion forces

The order listed above is **from greatest to least attractiveness.**

IMF Activities: Write out **what you did** and **what it means** for each of the activities we did.

Dipole-dipole Dance:

Dispersion Forces:

IMF Application:

1. When molecules have greater intermolecular attraction – what properties of the substance are affected?

   boiling + melting points

The following table demonstrates the effect of the dipole moment on the boiling point of several substances:

Substance	Molecular Mass [g/mol]	Dipole moment [Debye]	Normal Boiling Point [K]
Propane	44	0.1	231
Dimethyl ether	46	1.3	248
Chloromethane	50	2.0	249
Acetaldehyde	44	2.7	294
Acetonitrile	41	3.9	355

2. What do you notice about the relationship between the strength of the dipole and the boiling point of the substance?

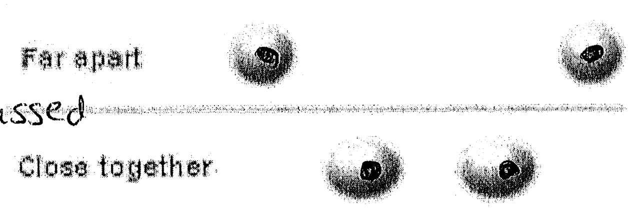
   As dipole - moment increases so does boiling point.

3. Look at the two substances with identical masses. Why do you think Acetaldehyde have a higher boiling point than Propane? What might you expect to find in its structure?

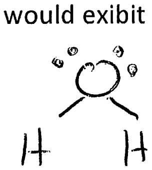
   Different bond type (ionic vs. covalent) greater electronegativity difference.

4. Which IMF is represented by the picture to the right?

   Dispersion forces time passed



5. Draw a molecule that would exibit hydrogen bonding.



POGIL #2 – Applications with Intermolecular Forces

Melting and Boiling Points

Solids			Liquids			Gases		
Element	Melting point (K)	Boiling point (K)	Element	Melting point (K)	Boiling point (K)	Element	Melting point (K)	Boiling point (K)
V	2190	3694	Hg	234	630	F	54	85
Te	723	1263	Br	266	333	Kr	116	120
Be	1560	2740				N	63	77

1. What is a melting point? What happens on the molecular level when substances melt?

   When a solid changes into a liquid.
   The molecules are moving further apart.

2. What patterns do you notice about the melting points of solids compared to liquids and also to gases?

   Solids - generally higher, bigger range in difference
   liquids - lower smaller range in difference

3. What is a boiling point? What happens on the molecular level when substances boil?

   When a liquid changes into a solid the molecules move farther a part and move at a very high speed.

4. Do the boiling points listed above have the same pattern as the melting points?

   Yes

5. Which kind of substance requires more energy to melt? Solids What do you thing that means about the attractive force between the atoms of this kind substance?

   The attractive forces are higher in solids

6. Rank the groups of elements above from the strongest attractive force between molecules to the weakest attractive force between molecules.

Compound	Melting point (K)	Boiling point (K)	Rankings
NaCl	1074	1738	2
K_2SO_4	1340	1962	1
SF_2	108	262	3
CH_4	91	112	4

7. Which two compounds have the strongest forces between molecules? Explain your choice.

   NaCl and K_2SO_4 They have the highest melting + boiling points.

8. What do these two compounds have in common?

   Ionic bonds/Compounds

9. Which two compounds have the weakest forces between molecules? Explain your choice.

SF_2 and CH_4 They have the lowest melting + boiling Points

10. What do these two compounds have in common?

Both covalent bonds

CONCLUSION:

11. Summarize what you have concluded regarding the ***strength of forces of attraction*** between molecules in compounds, *melting points*, *boiling points* and *types of intermolecular forces*.

Strong attraction	Weak attraction
Highest melting point Highest boiling point Ionic Bonds	Lowest melting point Lowest boiling point Covalent Bonds

the temperature at which the molecules of a substance have enough energy to transition from the liquid state to the gaseous state of matter	the degree to which electrons are shared equally or unequally between two atoms	the weakest form of intermolecular attraction where two nonpolar substances acquire a temporary dipole when in very near proximity to one another and for a brief moment are attracted to one another	a strong type of dipole-dipole attraction involving molecules containing a bond between one of the three most electronegative elements and hydrogen
a form of intermolecular attraction where the dipole of one molecule becomes attracted to the oppositely charged portion of the dipole of another molecule	forces of attraction experienced between molecules	the ability of an atom to attract bonding electrons to itself	the temperature at which the molecules of a substance have enough energy to transition from the solid state to the liquid state of matter
a bond characterized by an unequal sharing of electrons			